

2 [See pp. 35 ff., category 241 or 116. --
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Chapter II

THE SHIFTING CULTIVATOR

[p. 16]

241 The field of the shifting cultivator is known by various local terms. It is
361 called *caingin* in the Philippines, *humah* in Java, *ladang* in the Indies as a
311 whole and in Malaya, *taungya* in Burma, *tamrai* in Thailand, and *ray* in
Indochina.¹ Practically without exception, it is a clearing in either pri-
meval or second-growth forest. The use of grassland is so unusual that
we shall limit the following discussion to shifting cultivation on forest land.

As his name indicates, the shifting cultivator does not use the same
piece of land every year; instead, he kills or cuts down at regular intervals
—every year, every other year, or every third year—the trees of a small
forest patch. He burns as much of the woody growth as is possible or
convenient. Among the charred stumps and half-burned tree trunks he
plants his favorite crops, be they cereals such as millet, upland rice, or
maize; or tubers such as yams or sweet potatoes (Figs. 4-10). The latter
are planted extensively by the *caingero*, the shifting cultivator in the Phil-
ippines. In planting cereals it is usually the men who take the planting
stick to make little holes and the women who drop in a few seeds, using
their feet to cover the seed with soil (Figs. 11-13). As forest land is
generally free from weeds or grasses and the soil is usually rich in humus
and well supplied with the ash of burned plant matter after clearing, it
produces a very good, or even excellent, first harvest; the second harvest
begins to show a decline in yield, and thereafter the returns diminish
rapidly.² Grasses and weeds invade the clearing. Rather than battle these,
the peasant abandons his old *ladang* and cuts and burns a new patch of
forest (Fig. 15). The old plot reverts, under favorable conditions, to second-
growth forest, the so-called *blukar* of the Malays, and is not cleared again
for a period, the length of which may vary from 8 to 15 years, or more.

Shifting cultivation is characterized by a lack of tillage; the soil is
hardly disturbed, as no plow turns it. There is less labor involved than in
other methods of cultivation, and the work is more evenly spread over the
year—an advantage where labor is relatively scarce. The tasks involved
are cutting, burning, and planting; sometimes simple fencing of the field
against animals, guarding—especially before the harvest and usually by
women and children—and, finally, harvesting. In addition, there may be
some weeding in the first year and certainly during the second.

¹ In British India *jhum*, *kumri*, *dhya*, *bevar*, or *duller*; in Ceylon *chena*; in Japan, Korea, and Formosa *karen* (a Japanese term); in Central America *milpa*; in parts of Africa *chitemene*.

² Danhof reports for parts of the Lampoeng Districts that a *ladang* will produce from 15 to 25 quintals of rice in the first year and approximately 5 in the second year. In areas where the second yield shows such a serious decline the peasants usually prefer to make a new *ladang*—Danhof: "Bijdrage," 1940, p. 199.

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187 of the new ladang be a poor one. After three days the same person returns, and if he finds that the offerings have been scattered a new location is chosen and a new attempt is made to get a favorable answer from the spirits. In case the betel leaves have been found undisturbed, all male members of the village have a meal on the chosen land. Then the area is divided among the villagers by the headman. Each individual appeals to the spirits by placing a betel leaf with lime and areca nut on the ladang that has been turned over to him. If the answer is unfavorable he tries again. The betel leaf may be placed three times. If the offering is disturbed each time, the headman turns over a part of his share, which is considerably larger than any of the others, to the less fortunate villager. Throughout the following agricultural year with its stages of clearing, planting, and harvesting, the peasant repeatedly requires the services of the dukun, or *shaman*, as well as the betel leaf.

In other regions details differ, but the essential fact remains that the social-religious life and thinking of the shifting cultivator is bound up with his characteristic form of cultivation.

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621 Shifting cultivators have no concept of private land ownership. The land belongs to the community, the tribe, or the village, and each member has the right to use as much land as he needs and can cultivate. The location of the land that he is to use may be decided upon by the village council or the headman. The person who clears the land and plants the crop gets the produce. Nobody has the right to plant a plot that has been cleared by someone else. As soon as the land is abandoned all rights are forfeited, except the right of the community. However, if trees have been planted, the ownership of the trees and their produce remains with the person who planted them, and he is given preference when the land has had a sufficient fallow period and can again be cultivated.

THE EFFECT OF SHIFTING CULTIVATION ON THE LAND

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311 As has been stated above, ladangs decline in fertility after the first crop, and obnoxious grasses and weeds appear among the stooling tree stumps. As long as there is an abundance of forest land at his disposal the cultivator prefers to abandon the ladang. Under favorable conditions the grasses will, in turn, give way to second-growth forest. In the course of centuries this second-growth forest may develop into a climax forest, that is, a forest having the same composition as the primeval forest. In any case, when tall forest growth again occurs, the land will have had time to recover its original fertility.

Unfortunately, however, conditions are often not sufficiently favorable for a regeneration of soil fertility and the development of a good second-growth forest. As a matter of fact, the practice of shifting cultivation has altered the character of vegetation beyond recognition over wide areas in Southeastern Asia. Instead of a dense primeval rain-forest, we now find

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extensive open grasslands resulting from the most important tool of the shifting cultivator, fire.

Generally, the fallow period allows time only for the evolution of mediocre second-growth forest, for the shifting cultivator usually returns to an old ladang before even a small percentage of those tree species that made up the original stand have had a chance to come back. Repeated cultivations further impoverish the forest and reduce the number of species. Certain light-loving trees that played a minor role in the climax forest will spread rapidly and dominate, together with those species that show a resistance to fire and those that are capable of sending new sprouts out of the old stumps.⁵

If fire repeatedly invades an abandoned ladang, the tree flora is reduced until finally only grasses and herbs survive. These persist because their root systems, tubers, or bulbs send out new shoots after the fire. The more important grasses and herbs that finally triumph over forest vegetation are *Imperata cylindrica* Beauv., *Imperata constricta* Hitchc., *Saccharum spontaneum* L., *Themeda gigantea* Hack, and *Eupatorium odoratum* L. These burn very rapidly and with a hot flame, even when still green. After they are well established they catch fire or are set afire every year, almost without exception; this prevents natural reforestation. Furthermore, the fire will also invade the neighboring forest and force it gradually back, so that the grass area steadily increases. This is especially true in hilly or mountainous country. In the Philippines about 18 per cent of the total area is covered with grass vegetation as a result of shifting cultivation and fires. These grass areas are known locally as *cogonales*. In the Indies, where they are called *alang-alang*,⁶ they are also extensive, as in southern Sumatra. While I was traveling through southern Sumatra by rail during the dry season I counted twenty grass fires started within the space of an hour by sparks from our locomotive. In Thailand there is as yet very little cogonal land, according to Pendleton.⁷ In Indochina culturally induced grasslands, either pure or with scattered trees—the latter called by the French *forêts claires* or *savanes-pares*—are very extensive⁸ (Figs. 23, 24) 241

Once the vegetation of an area has been changed from forest to grass, the land is of no more agricultural use to the shifting cultivator. The only benefit that he then gets out of the land is for hunting. For this, too, he often utilizes fire—either to drive wild animals out of hiding or to get a growth of young grass to attract his prey. 134 311

⁵ In Malaya and Sumatra the spread of such bushes and trees as *Lantana camara* L., *Schima bancana* Miq., *Peronema canescens* Jack, *Vitex pubescens* Vahl, *Melastoma malabathricum* L., and *Lagerstroemia speciosa* Pers. is due to the cutting of clearings.

⁶ *Imperata* (both *constricta* and *cylindrica*) is known in the Philippines by the Spanish term *cogon*, in the East Indies as *alang-alang*, and in Malaya as *alang*. The last two are Malay words.

⁷ Pendleton: "Some Interrelations between Agriculture and Forestry," 1939, p. 41.

⁸ Gourou: L'utilisation du sol, 1940, pp. 368-372.

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When fires no longer ravage the grasslands, however, trees return and finally drive out the grasses completely, for the latter cannot stand shade.⁹

The spread of grass is especially rapid in regions with a long, pronounced dry season, whereas reforestation is more likely to take place in areas with a well distributed, high annual rainfall. This may explain why the Philippines and Indochina have a larger percentage of open grasslands than do Malaya and the Netherlands Indies.

A relatively high density of population is an important factor in preventing successful reforestation and encouraging grasses. In a thinly settled forest area there is sufficient land to allow for a long rest period, but an increasing density of population results in the shortening of the fallow period to such a degree that the soil is given insufficient time to recover its fertility. The shorter the fallow period the poorer the succeeding forest—if any—and the poorer the following crop yields, until finally the land can no longer satisfy the needs of the shifting cultivator.

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Pendleton believes that this cycle may have contributed materially to the downfall of the Khmers in Cambodia (Cambodge). He states that although the Khmers used the plow on very limited areas of wet riceland, they had largely to depend on the planting stick and shifting cultivation for their food supply. As the demands for more food arose from the rapidly increasing population concentrated in the city of Angkor, the fallow period granted to the uplands had to be progressively shortened. At the same time fires became so frequent that culturally induced grasslands spread while the cultivable area decreased, thus further diminishing the food supply available to the people of Angkor. "While the actual fall of Angkor is ascribed to the superior military power of invaders, the resistance of the inhabitants was doubtless much less than it would have been had the lands been productive and they had had adequate supplies of food."¹⁰

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Declining crop yields and the spread of grasses have been advanced as important reasons for the breakdown of the Mayan civilization,¹¹ and Pendleton further raises the question "whether the development of cogonals might not have been an important contributing factor in the dying out of some of the other civilizations of the tropics, notably that of Anuradapura, in Ceylon."¹²

Today the ruins of the Mayan cities, as well as those of Angkor, are surrounded by relatively luxuriant forest vegetation, which has had time to displace the pernicious grasses since man and his tool, fire, have abandoned the inhospitable grasslands.

Not only does shifting cultivation alter the character of the vegetation,

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⁹ When an old ladang remains unburned for several years the following trees spring up in addition to those already mentioned in footnote 5: *Erechthites hieracifolia* Rafin., *Blumea balsamifera* DC., *Peltophorum dasyrachis* Kurz, *Macaranga tanarius* Muell. Arg., and *Piper aduncum* L.

¹⁰ Pendleton: *op. cit.*, pp. 46 and 47.

¹¹ Cook: "Milpa Agriculture," 1921, pp. 307-326.

¹² Pendleton: *op. cit.*, p. 47.

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Not only does shifting cultivation alter the character of the vegetation, but also it may induce soil erosion, especially when it is practiced on slopes. Forest vegetation keeps the soil from being washed or blown away, but at the end of the dry season, when the trees have been cut and burned, the soil lies exposed. Consequently, during the early days of the rainy season large quantities of topsoil are washed downhill and carried by rivers to the plains. Erosion, by lowering the moisture-holding capacity of the soil as well as the rate of absorption, may thus cause further acceleration of run-off and lead finally to destructive floods on the plains. Such floods are frequent in the Philippines and parts of the East Indies. Pendleton points out that in Thailand the main rivers receive their great load of silt from the more steeply sloping mountains of northern Thailand where shifting cultivators have started the forces of accelerated erosion.¹³

The large quantities of valuable timber destroyed year after year by the shifting cultivators in virgin areas and the prevention of reforestation by the fires that spread through the abandoned fields (Fig. 22) cause the forester to regard the shifting cultivator as his enemy. In the Philippines the forester has for many years been pleading for strictly enforced laws and severe penalties against shifting cultivators.

The greatest enemy of our forest is *cañgin* making. It is to the persistent practice of this crude form of agriculture from time immemorial that the existence of vast areas of denuded waste lands is attributable. Much of our valuable timber has been and is still being wasted by this illegal form of forest clearing. There are actually over five and a half million hectares of open lands that are practically idle. Due to continued *cañgins* and the recurrence of fires on these open lands, the forest area is decreasing year after year. . . . Destructive floods in various parts of the Islands and the yearly appearance . . . of locust pest, the extermination of which is costing the Government hundreds of thousands of pesos yearly, are chiefly the direct results of this obnoxious practice.¹⁴

CONFLICTING VIEWS ON THE MERITS OF SHIFTING CULTIVATION

Judgments on the merits of shifting cultivation have been rather contradictory since the practice first came to the attention of scientific observers. During the past century the Dutch in Java spoke of it as *Raubbau* (robber economy), and one still finds the expression used. Sauer protests against this term. According to him, shifting cultivation is a "primitive economy, in which the per capita area of land needed for a community is rather large and in which the forest growth is to be considered as a part of a long term rotation of fields." He is of the opinion that it is "an excellent device for maintaining permanent productivity."¹⁵

Lord Hailey calls shifting cultivation "less a device of barbarism than a concession to the character of a soil which needs long periods for recovery and regeneration; and the trekking habit, whether of Dutch farmers

¹³ Pendleton: "Soil Erosion in the Tropics," 1940, p. 757.

¹⁴ Letter of the Director of the Bureau of Forestry to the Secretary of Justice, September 10, 1934.

¹⁵ Sauer: "Destructive Exploitation," 1938, p. 406.

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THE AREAL EXTENT OF SHIFTING CULTIVATION IN SOUTHEASTERN ASIA

It is difficult to form an idea of the areal extent of shifting cultivation because of its migratory nature and the fact that it is often practiced in remote regions. The only country of Southeastern Asia in which an attempt has been made to estimate the area used for shifting cultivation is the Netherlands Indies, but even there it was not possible to include all

TABLE II—PHILIPPINE ISLANDS: ILLEGAL CAINGGINS DETECTED, 1914-1940

YEAR	ILLEGAL CAINGGINS	
	NUMBER	AREA IN HECTARES
1914	895	
1915	1 198	
1916	845	
1917	665	
1918	776	
1919	603	
1920	721	
1921	602	1 429.48
1922	1 110	2 803.55
1923	759	1 516.33
1924	1 753	1 396.90
1925	1 761	1 391.20
1926	1 820	1 476.61
1927	2 002	1 743.92
1928	1 774	1 602.95
1929	1 312	1 370.41
1930	3 227	3 279.77
1931	2 534	3 345.74
1932	2 547	5 586.27
1933	2 427	2 831.38
1934	3 207	3 215.46
1935	2 631	2 455.73
1936	2 314	2 510.59
1937	1 967	2 308.24
1938	1 766	2 029.68
1939*	906	1 331.12
1940†	2 646	4 416.56
Total	48 778	48 071.98

Source: Data supplied by the Bureau of Forestry, Manila.

*Six months only, ending June 30, 1939, because of change of fiscal year.

†From July 1, 1939, to June 30, 1940.

parts of the Outer Islands in the estimate. Van Benkerling concluded that one-third of all food consumed in the Outer Islands was grown on ladang; this would require a total of 1,100,000 hectares of land. If we assume that all ladangs are occupied for 2 years and lie fallow for 12 years, the shifting cultivation system would need seven times 1,100,000, or 7,700,000, hectares. This estimate does not include the ladang area under coffee and pepper cultivation. (Rubber, coconut, and benzoin cannot be considered because they are, for practical purposes, permanent crops.)

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Van Beukering allowed an additional 200,000 hectares for coffee and pepper ladangs; so that the total area amounts to about 8,000,000 hectares. If we assume that the population of the Outer Islands increases at the rate of $1\frac{1}{2}$ to $2\frac{1}{2}$ per cent each year, it would double in from 29 to 47 years. This would mean that after about 30 to 50 years 16,000,000 hectares would come within the scope of shifting cultivation.

In Malaya ladang cultivation is illegal, but it is practiced in the hinterland well away from roads and railways, in eastern sections of the peninsula. Dobby recently described it in Pahang and northeastern Kedah, near the Thai border.³⁰ The Sakai of Pahang regularly abandon their primitive huts as well as the clearings when they shift to a new field (Map, Fig. 2).¹ The Malays of northeastern Kedah, on the other hand, as a rule live permanently in one place and change only their fields (Map, Fig. 3).¹ There are no statistics available on the areal extent to which shifting cultivation is carried on in Malaya, but according to Dobby the system gives way to permanent culture "as the standard of cultivation rises and as the effect of law becomes stronger."³¹

In Thailand shifting cultivation is extensively practiced by the tribes of the mountains of the north and west, on the eastern part of the Khorat Plateau, and on the peninsula. Probably about 1,000,000 people depend upon it. According to the same kind of calculation that Van Beukering made for the Indies, a total of 1,400,000 hectares would be required, or 200,000 hectares annually, if we allow five persons per household and consider that one hectare covers the needs of a family for 2 years.³²

[162] In Indochina only the tribes of the mountains of Tongking, Laos, and Annam now practice rây, or shifting, cultivation. The people of the plains, Annamese and Cambodians, who represent 84 per cent of the population, practice a more intensive form of agriculture. Gourou has estimated the areal extent of shifting cultivation in Indochina. He states that a rây is used for 2 years and has to lie fallow for at least 20 years, which seems a rather long period as compared with other countries. In addition to its extensive plains, Indochina has a mountainous or hilly area of 580,000 square kilometers. Only one per cent of this land is permanently cultivated. Gourou estimates that about 40 per cent of the mountainous country is suitable for rây cultivation and he assumes that one-tenth of this, or 4 per cent of the total mountain land, is under rây cultivation in any one year.³³ If this calculation is correct it would mean that 23,200 square kilometers, or 2,320,000 hectares, are occupied annually by shifting cultivators. The numerical strength of the shifting tribes shows, however, that this estimate cannot be correct. Their number is not much greater than

³⁰ Dobby: "Settlement Patterns in Malaya," 1943, p. 222.

³¹ *Ibid.*

³² For an excellent description of the life of the shifting cultivators in Thailand, see Credner: Siam, 1935, pp. 148-173.

³³ Gourou: L'utilisation du sol, 1940, pp. 177-182, especially pp. 180 and 182.

[see p. 27, category 116. -- Analyst]

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1,500,000, or at the most 2,000,000, which would mean about 300,000 to 400,000 households. This number of households could hardly occupy such a large rāy area as Gourou assumes. 241
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In Formosa only the Malay tribes of the mountains in the eastern half of the island practice shifting cultivation. They number, according to estimates, about 150,000. From this we may assume that not more than 30,000 to 50,000 hectares are occupied annually by shifting cultivators. 134

In the Philippines it is unlawful to make cañigins on public land without the permission of the Bureau of Forestry.²⁴ Permission will be given if the forest on the land involved is of no commercial value and if the cañigero accepts the obligation to reforest his patch with seeds supplied by the forest service. Several hundred cañigeros are brought annually before the justices of the peace, who in the past, because their sympathy was with the cañigeros, were usually rather reluctant to fine the culprits (Table II).² Nobody knows, of course, how many illegal cañigins escape detection, but it is certain that they greatly outnumber those that are made with the permission of the foresters added to those that have been brought to the attention of the courts. Special consideration is given to the "non-Christian" tribes, for whom tracts of land have been set aside within which they continue their age-old system of cultivation. In Mindanao probably three-fourths of the population, from the primitive Manobos to the more advanced Moros, practice the cañigin system of cultivation. Other regions where this system is practiced extensively are Mindoro, Cebu, southern Negros, and parts of Luzon—the central and eastern cordillera and the Camarines. About 10 per cent of the population of the Philippines obtain a part or all of their food from cañigins, most of which are made either on private land or on land that belongs to non-Christian tribes who know no other form of agriculture. [62]

METHODS OF ELIMINATING THE UNDESIRABLE ASPECTS OF
SHIFTING CULTIVATION

In regions where the density of population exceeds 50 persons per square kilometer, shifting cultivation becomes wasteful and destructive. It is imperative in such areas that the system be either modified or else replaced by more conserving and, where possible, more intensive forms of land use. For most backward tribes this involves fundamental changes in their mode of life, religious ideas, and concepts of land rights. 241
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In some instances it should suffice to adopt measures that eliminate the harmful or wasteful after effects of the system without requiring that this kind of land use be given up completely. Let us assume that we have a somewhat thinly settled region containing a forest that is not particularly valuable and the exploitation of which is impracticable or at present inexpedient. Deforestation and the spread of grasses are undesirable aspects 185
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²⁴ Nanno: "Kaiñgin Laws," 1939, pp. 87-92.

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recuperate quickly when the area is again allowed to revert to bush."³⁸

Several of the forest services of Southeastern Asia have made a rather successful use of the shifting cultivator in their endeavor to reforest the land. They have combined shifting culture and silviculture by hiring shifting cultivators to cut mature trees and to sow or plant new trees on cut-over or burned-over land. For this the cultivators are paid a small wage. In addition they are allowed to grow their own crops for one or two years between the rows of young trees. This system, known as the "taungya forestry system," was developed in 1856 by the German forester, Dietrich Brandis, while he was Superintendent of Forests in Pegu, Burma.³⁹ It is ingenious in that it recognizes the habits of the shifting cultivator and fits them into a modern forest economy instead of persecuting the cultivator and forcing him to give up his traditional culture. This system has been used in the teak forests of Java since 1871. The forest service makes a contract⁴⁰ with the peasants of Java according to which the peasants are to prepare the land and plant and take care of teak trees (*Tectona grandis* L.) in return for a small sum of money and the right to plant such crops as maize and red pepper (*Capsicum annuum* L.) between the rows of teak. The cultivation of upland rice is discouraged, and the planting of cassava, peanuts, castor beans, and tobacco usually is not allowed (Fig. 40, 41). ²⁴⁵ [654] 185

The taungya forestry system is an excellent way of getting pure stands of commercial timber. The typical forest of the tropics is expensive to exploit because of the large variety of trees which it contains, many of which have little or no commercial value.⁴¹ [313]

As important as reforestation is soil erosion control. Where shifting cultivation is practiced in mountainous regions it often causes such acceleration in the rate of erosion that the rivers are choked with sediment and periodically do great flood damage. Flood control could be achieved in most cases by completely closing the headwaters and watershed areas to cultivators. On more gentle slopes the clearings should be rather narrow, should parallel the contours, and be separated by belts of forest. If at the same time the forest uphill were protected by fireguards, the clearings would have a chance to close quickly again so that the soil would be ¹³⁴ ¹³³ 185

³⁸ Worthington: Science in Africa, 1938, pp. 378-379.

³⁹ Taungya is the Burmese term for the temporary field of the shifting cultivator, a term that the foresters have adopted. E. P. Stebbing in his work, The Forests of India, Vol. 1, 1922, p. 376, writes:

"Brandis, moreover, recognized that the very system which, till then, had destroyed teak forests might be utilized to produce them, . . . and as early as 1856 an attempt was made in Promé district to sow teak in regular rows, together with the rice scattered by the taungya [*sic*] cutters. Twenty years afterwards this attempt had grown into a regular system, by which areas were being annually stocked with teak at a cost far below that of regular plantations." See also *Ibid.*, Vol. 3, 1926, pp. 415-428.

⁴⁰ Becking: "De djaticultuur op Java," 1928, pp. 50-52.

⁴¹ Heske: "Der tropische Wald," 1939, p. 414. Heske's article gives an excellent short account of the forests of Southeastern Asia and points out that they are on the whole much easier to exploit than are the forests of tropical America because of the abundance of cheap labor.

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protected against abnormal erosion. Terracing would be the most effective method of checking soil erosion, but this requires a good deal of labor, which is scarce in areas of shifting cultivation.

The Forestry Service of the Indies started an interesting soil-erosion experiment near Tjiwidej in the mountains south of Bandoeng at an elevation of 1800 meters. Two adjacent parcels of forest land, lying on rather steep slopes, are drained separately—out of each parcel comes a little brook—and thus form separate drainage units. Both parcels were used by shifting cultivators who had cut and burned the forest. In one case the slope was left undisturbed; in the other the slope was terraced. At the foot of each slope catch basins were constructed to retain the sediment that was washed down by rain water and transported by the brooks. The amount of water that drains out of each unit was measured and the sediment weighed. The purpose of this experiment was to get quantitative measurements of the amount of erosion that is caused by shifting cultivation and to study the effect of terracing in reducing soil loss. During the first year both parcels lost very little soil, because the humus layer protected it; but in the second year the unterraced parcel lost 5.065 kg. of silt per square meter whereas the terraced parcel lost only one-half as much, or 2.524 kg.⁴² (Figs. 42-45).

Under the conditions that we have discussed so far, no radical change in the system of cultivation is required. If, however, the population increases to such an extent that there is no longer enough available land to allow for a sufficiently long rotation cycle, more drastic remedies are necessary.

Such a situation arose in parts of the Outer Islands and attracted the attention of government specialists. Legal experts familiar with Indonesian customary law, foresters, and agricultural advisers collaborated to seek a solution.⁴³ Realizing that shifting cultivators are usually reluctant to give up their traditional form of land use, the specialists approached the ladang problem by searching for means of reforesting ladangs quickly. Experiments were made with the planting of quick-growing leguminous and non-leguminous trees, bushes, and shrubs to shorten the fallow period, restore the humus, protect the soil against accelerated erosion, eliminate the grasses, and, in the case of leguminous species, improve the soil by adding nitrogen.⁴⁴ We have already seen, however, that artificial refor-

⁴² I was able to visit the Tjiwidej experiment with Mr. L. Gonggrijp, under whose supervision the work was carried out. For a detailed report on the project see Gonggrijp: "Het erosie-onderzoek," 1941, pp. 200-220.

⁴³ H. J. Friedericy of the Department of the Interior and H. Vonk and E. J. Wind of the Department of Economic Affairs, for example, worked together on the problem of ladang culture in the residency of Palembang.

⁴⁴ Experimental plantings included, among others, *Erythrina lithosperma* Miq., a light-loving tree which is typical in Southeastern Asia of dry, rather open climax forests and of second-growth forests; *Hibiscus tiliaceus* L.; *Albizzia falcata* Backer, one of the fastest-growing trees of Southeastern Asia, used widely as a shade tree on coffee plantations; *Aleurites moluccana* Willd., a tree at home in the drier parts of the East Indies; *Leucaena glauca* Benth.; *Pterocarpus indicus* Willd., a large tree frequently used along roadsides as

1. [see p. 42, category 116 -- Analyst]

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estation is not a discovery of Western-trained scientists but has long been practiced by certain groups in Southeastern Asia. It was the plan of the government to spread and enforce this practice of artificial reforestation wherever advisable. This practice, whereby the cultivator determines the vegetative cover during the fallow period instead of abandoning the ladang to chance growth, brings him to a transition stage between shifting cultivation and permanent cultivation. From there the step to permanent cultivation with crop rotation is but a short one.

Permanent cultivation requires repeated tilling and therefore more labor and tools than the shifting cultivator is accustomed to. Work animals are also desirable. An important obstacle to intensification of agriculture in wide areas of Southeastern Asia, however, is the fact that hill and mountain regions [up to about 1,500 meters in elevation] are frequently infested with malaria so that the energy of the people is greatly reduced.⁴⁵ Moreover, the acquisition of such implements as plows, harrows, and hoes, and especially of work animals, calls for financial resources or credit, both of which the average shifting cultivator lacks. Some shifting cultivators do own livestock, such as cattle or carabaos, but utilize neither their labor nor their manure. Groups of the Mois in the mountains of Annam have carabaos, but they do not use the animals in their agricultural activities because they "cannot talk" to them.⁴⁶ On the Lesser Sunda Islands livestock is kept because it gives social prestige to the owner. Overstocking of the pasture areas on these islands has led to overgrazing and has cut into the forest area until there has developed a scarcity of land suitable for ladang cultivation. The same has happened in large areas in Africa. There it has been necessary to teach the native peasant the use of cattle and make him familiar with the plow. This was done successfully in northern Nigeria by combining the animal husbandry of the nomadic Fulani with the indigenous shifting cultivation of the Hausa peasant, thus developing "a system of permanent farming whereby a man with cattle of his own, say two working oxen and a few cows, can plough and maintain in fertility an area of land sufficient to supply all the requirements of himself and his family, and to obtain a surplus balance as a return for his labour. . . . Thus mixed farming represents a gradual evolution from the shifting methods of cultivation to a static type of agriculture, by the introduction of animal husbandry, and with the use of animal cultivation."⁴⁷ Above all, the peasant learns to preserve the animal manure and

a shade tree; *Dolichos lablab* L., a climbing herb which is valuable as a vegetable; *Crotalaria anagyroides* H.B. and K., a bush of vigorous growth which attains a height of from 12 to 14 feet and forms an excellent green manure; *Tephrosia candida* DC. and *Tephrosia vogelii* Hook., low shrubs useful as green manures; and *Mimosa invisa* Mart., a leguminous creeper which suppresses grasses.

⁴⁵ Gourou: L'utilisation du sol, 1940, pp. 181 and 330.

⁴⁶ *Ibid.*, p. 354.

⁴⁷ King: "Mixed Farming in Northern Nigeria," 1939, p. 271. See also Faulkner and Mackie: West African Agriculture, 1933; and by the same authors: "The Introduction of Mixed Farming in Northern Nigeria," 1936, pp. 89-96.

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who does not know where he will be the next year cannot be expected to plant fruit trees. Under these conditions the diet is reduced to the simplest foods and is usually deficient.

Zimmerman criticizes some of the characteristics of garden culture in the Thai part of the Malay Peninsula. The improvements that he recommends show that he has approached the gardens with a Western eye, looking for fruit trees "in rows at proper spaces, not scattered as is the case now."⁶ He notices lack of tilling, an observation that could be duplicated in every country of Southeastern Asia. As a matter of fact, it is fortunate that the gardens—especially those that have many fruit trees and palms—are not clean-cultivated; otherwise erosion would have caused the same damage here that it has caused in the Westerners' rubber, tea, and coffee plantations—these were planted in rows and kept clean until the discovery was made that soil erosion is extremely severe under such conditions. Pendleton remarks:

The average Occidental, accustomed as he is to clean cultivated orchards and vineyards in temperate zones, is inclined to keep a plantation in the tropics likewise cultivated. This is now quite generally recognized as a mistake. . . . Near Songkla [in southern Thailand] . . . are considerable plantings of fruit trees, planted as if they were forest trees. . . . Annually, before harvesting the fruit, the undergrowth is slashed and left on the ground, but there is no stirring of the soil or other cultivation. The results are excellent, and there is no soil deterioration, no catastrophic erosion, no expense for cultivation.⁷

245 There is little literature on the importance of garden culture among the Malays of British Malaya. According to Grist,

fruit cultivation is of little more than local importance. The total area under fruit, other than pineapples, is estimated to be 63,000 acres. . . . This area does not take into account the numerous small compounds surrounding Malay homesteads, in which a few fruit trees are planted and which, in the aggregate, must amount to a very considerable area. Although certain fruits acquire a reputation in particular localities, the distribution of the fruits is scattered throughout the country. For instance, North Johore is noted for its durians, Malacca for dukus [*Lansium domesticum* Jack], Penang for rambutans, but in point of fact, equally good quality fruit of these kinds can be found in other areas.⁸

Malaya lacks the detailed information about gardens and their economic importance that is found in Java, for instance, where the garden area of each village is known, because in Malaya there is no population pressure and therefore no need for exact field studies and careful inventories of the source of food supply.

The Philippines are like Malaya in respect to garden culture. Some districts around Manila Bay have specialized in such fruits as mangoes,

⁶ *Ibid.*, p. 163.

⁷ Pendleton: "Some Interrelations," 1939, p. 50.

⁸ Grist: *An Outline of Malayan Agriculture*, 1936, p. 228.

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Irrigation systems also fall into two categories: peasant irrigation works and technical irrigation works. The former have existed throughout Southeastern Asia for more than a thousand years. In recent times scientifically trained engineers have designed large-scale systems with concrete weirs and locks. Fields solely dependent upon impounded rain water produce one rice crop a year, whereas irrigated fields often yield two crops. If even with irrigation only one crop can be produced, yet the irrigation system assures proper water control, whereas without it irregularities in the course of the rainy season may damage, or destroy, the crop.

Wet fields are protected against erosion by leveling, terracing, and dyking. But how does continued cropping affect the fertility of wet-rice fields? Diverse environments and cultural practices in Southeastern Asia create considerable differences in this respect. Much of the paddy land of the Philippines, Indochina, Thailand, Malaya, and Burma has lost a good deal of its original fertility because the peasants have not used manures, fertilizers, or crop rotation. In many instances, however, soil fertility has been preserved by the mineral matter dissolved in the irrigation water and by the silt deposited on those fields that are supplied with irrigation water coming from streams. The value of the water and silt depends, of course, upon the nature of the parent material from which it is derived. Rivers from a young volcanic region supply much richer water and silt than do those that drain a mountain region consisting of sedimentary rock or granite. For this reason, the Irrigation Service of the Netherlands Indies before making final plans for a new irrigation system takes samples of water and silt carried by rivers at different times of the year. The samples are analyzed in order to determine their influence upon the soil to be irrigated. A river found to be carrying water and silt that would lower the value of paddy land would be eliminated as a source of irrigation water, or its use would be limited as much as possible.

Irrigated fields of which the water supply does not contain minerals in quantities necessary for continuous satisfactory plant growth and paddy land that depends exclusively upon rain, both require other techniques for maintaining fertility. In many regions cultivators cut the rice stems just far enough below the ear to allow bundling. This practice makes possible the return of the rest of the plant matter to the soil. From this it is only one more step to work household refuse into the ground together with ashes of burned rubbish, rice husks, leaves, and manure.

As stable manure is not available in adequate quantities, intensive studies of the application of green manures to the cultivation of rice have been made in a number of countries of Southeastern Asia. A recent article by W. Bally reviews the results of these studies.¹⁴ In a few rice-growing regions the peasants, on their own initiative, have learned to use legumes to improve rice soil. In wet fields the decomposition of green manure takes place under anaerobic conditions, and the final product is ammonia. Since

¹⁴ Bally: "The Employment of Green Manures," 1936, pp. T10-T31.

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rice takes up nitrogen in the form of ammonia, the value of green manures on wet-rice fields is apparent.¹⁵ In the Indies, *Crotalaria* species are the most frequently used green manures, the favored one being *Crotalaria juncea* L.; but *Phaseolus lunatus* L., *Dolichos lablab* L., and *Pachyrhizus erosus* Urban are also used. The peasants of the Red River delta in Tongking are in the habit of working into the ground the wilted matter of a number of legumes that have been grown primarily for seed. The peasants of the province of Nam Dinh have developed a technique that may be unique. They push handfuls of indigo branches into the ground between the rows of rice a few days after the latter has been transplanted, for they believe that indigo is superior to pig manure or human excreta. In Indochina rice-growers frequently cultivate green manure, especially *Crotalaria* species, on dry fields and carry it to the rice fields at the time when these fields are being prepared for the seedlings. A green manure used exclusively in a few districts of the delta land of Tongking is the small aquatic plant, *azolla*.¹⁶ Certain villages, thanks to favorable circumstances, have specialized in the growing of *azolla* to sell to the surrounding country, while other villages reproduce the plant until sufficient quantities of green manure have been obtained to cover all needs. The life cycle of *azolla* is completed in the months from November to April or May. Only the villagers of La Van know the secret of maintaining and multiplying the plant during the hot season. They guard this secret jealously since it is the basis of their livelihood.

Further studies are needed to establish which varieties of green manure plants are best suited to the various environmental conditions. It is important to find plants that grow rapidly and can be sown when the rice is still on the field, just after the water has been drained off to allow the grain to ripen. Experiments should also be made in the timing of the application of green manure. Should it be early, or just before the transplanting of the seedlings? Should it be on dry or on wet land?

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Crop rotation also has its place as a means of keeping up the fertility of wet-rice fields. This practice seems to be better developed and more prevalent in Java than in any other country of Southeastern Asia. Extensive areas of *sawah*, as the Javanese call their wet riceland, are planted with dry-field crops such as maize, legumes, and other vegetables during the dry season, a practice that has a beneficial effect upon the soil. This form of double cropping is probably better than raising two rice crops in one year, because—although a different variety of rice is chosen for each season—both make essentially the same demands upon the soil; whereas a peanut crop, for example, grown during the dry season will enlarge the nitrogen content of the soil. In some areas of Java lowland rice is rotated

¹⁵ Imperial Bureau of Soil Science: *Tropical Soils in Relation to Tropical Crops*, 1936, p. 11.

¹⁶ For a map showing the extent of the use of *azolla*, see Gourou: *Les paysans*, 1936, p. 392. For further discussion see Nguyễn-công-Tiêu: "L'azolle," 1930, B, pp. 335-350 (also in *Proc. Fourth Pacific Science Congress, Java, 1929*, Vol. 4, 1930, pp. 355-370).

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with sugar or tobacco grown under plantation management. But is the high fertility of the soil due to this crop rotation, or is it rather the result of the heavy application of commercial fertilizer and the thorough cultivation of the soil under Western management?

In no country of Southeastern Asia is there so great a variety or so intensive a use of commercial fertilizers as in Japan.¹⁷ In general, the peasants of Southeastern Asia lack money for commercial fertilizers. In Indochina local phosphates are within reach of some of the Annamese, but the costs of imported fertilizers are prohibitive. In Java, although attempts to make possible the use of fertilizers through the agency of public credit institutions were successful in some special instances, not more than one per cent of the cultivated area received any commercial fertilizer in 1939. On the other hand, estimates indicate that more than 1,000,000 hectares of sawah have a phosphate deficiency and that a moderate application of phosphate would augment the yield by 25 to 50 per cent.¹⁸

The Agricultural Advisory Service was able to raise the productivity of wet-rice fields in West Java by about 10 per cent. It encouraged the peasants to use fertilizer on seedbeds, to sow rice more thinly on the beds (thus producing stronger seedlings), and to plant the seedlings in rows so that weeding could be done with a special instrument, the *landak* (Fig. 59). This weeder was developed in Japan. During the years immediately preceding 1939, these improvements in West Java resulted in an increase in output of unhusked rice amounting to 300,000 quintals, or 30,000 metric tons, with a value of nearly 1,000,000 guilders. This shows that some improvements in cultivation may increase production without a great capital outlay.¹⁹

Java may be compared only with southern China and with Japan in the cleanness of its rice fields. The Filipino does not pay much attention to weeding. The Malayan, Thai, Cambodian, Cochinchinese, and Filipino rice farmers have more flooded riceland per capita at their disposal than the people of Java and can thus afford to cultivate their land less intensively.

Irrigation Problems

Peasant irrigation works usually take care of the fields of only one village or of a small group of people who have joined together for the specific purpose of building and maintaining an irrigation system. These works consequently are small and usually inadequate, but nevertheless they de-

¹⁷ "The chief commercial fertilizers used in Japan are pressed herrings, pressed sardines, dried sardines, other fish cakes, bone meal, soybean cake, rapeseed cake, cottonseed cake, other vegetable-oil cakes, ammonium sulphate, calcium cyanamide, calcium phosphate, and potassium phosphate. Calcium phosphate and ammonium sulphate are probably the most representative chemical fertilizers."—Wickizer and Bennett: *The Rice Economy*, 1941, p. 252, footnote 33.

¹⁸ Departement van Economische Zaken: Voedselproblemen, 1940, p. 28.

¹⁹ *Ibid.*, pp. 27-28.

² [see p. 117, category 116. -- Analyst]

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yields. On the whole, the farmers of Cochinchina cultivate their fields much less intensively than do those of Tongking and Annam. Hardly any double cropping of rice is practiced in Cochinchina, nor is much of the riceland cultivated during the dry season.

In 1941 changes in the political boundary between Thailand and French Indochina reduced the importance of Cambodia as a rice-surplus region of Indochina. Cambodia lost the Battambang area, west of the Tonle Sap, which in recent years had developed into a prosperous rice-growing district, possessing one of the most modern rice mills of Indochina.⁴⁷ The province of Battambang has a rice area of 134,000 hectares, whereas Cambodia, before the boundary change, had about 800,000 hectares of rice-land.⁴⁸ Most of this is cultivated during the rainy season and depends entirely upon the rain caught in the fields. Around the Tonle Sap and along the Mekong a good deal of floating rice is grown, and some riceland is planted after the summer flood has receded. The crop from this land is harvested in the dry season and may be considered a dry-season crop, although it begins to grow during the latter part of the rainy season and profits from the floodwater that has spread over the land.

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The deltas of the Red River and of the Mekong, the two "rice baskets" of Indochina, differ greatly when it comes to the final disposal of the crop. The contents of the Tongkingese basket barely meet the needs of the local population, whereas a large part of the Cochinchinese rice may be exported, since the production far exceeds the local consumption. The delta of the Red River is densely settled; but Cochinchina, especially the western part, is still a pioneer country with a relatively low population density. The importance of Indochina as a rice-exporting region is based entirely on the production of rice in the south, particularly in Cochinchina and, to a lesser extent, in Cambodia.

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DRY FIELDS

Dry fields⁴⁹ represent the third type of land under permanent cultivation in Southeastern Asia. The steady increase in the foreign demand for tropical products raised on dry fields, combined with the growth in local food requirements, has led to a great expansion of the area under permanent cultivation. The continuous use of unirrigated land, however, offers one of the most troublesome problems of tropical agriculture, because of the difficulty of preventing soil depletion. Erosion is especially active in a

⁴⁷ Thompson: "War and Further India's Rice," 1941, p. 185.

⁴⁸ Gourou: *L'utilisation du sol*, 1940, p. 309.

⁴⁹ In the following discussion we shall exclude non-irrigated or dry land that comes under the regime of shifting cultivation. Sometimes a non-irrigated field lying fallow may have the same appearance as a recently abandoned ladang. But the essential difference is that under permanent culture land tenure is more highly developed than under shifting culture; so that a permanent field lying fallow belongs to an individual who, after a short period, will again cultivate it, whereas an abandoned ladang gives the former cultivator no claims for the future.

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climate characterized by heavy rainfall often concentrated in one season, and it will, unless checked, lead to the exhaustion of the fertility of the soil at a comparatively rapid rate in the tropics. In Southeastern Asia permanent dry fields are usually found on sloping ground exposed, much more than in the case of garden or wet-rice land, to the danger of erosion. Garden land is protected by dense stands of perennials, while terracing and dyking guard wet fields against destructive erosion. The terracing of dry fields is one of the most effective ways to control the loss of soil, but, since terracing requires so much labor, we find terraced dry fields only in densely settled regions, and even there the peasants often will not undertake this additional labor unless they are urged to do so by the authorities. As long as there is enough land available, the peasants prefer to let dry land recuperate by lying fallow for short periods rather than to protect it by terraces; but with the increasing density of population and the consequent shrinkage in the size of individual farms this practice is no longer possible (Figs. 61-64). ⁵⁰

As early as the second half of the nineteenth century, K. F. Holle, the agricultural adviser in the Netherlands Indies, constantly stressed the need of controlling erosion on dry fields. Following his advice, the government, in Article 5 of the 1874 Ordinance on Alienation of Domain Forest Land, stipulated that permission to clear domain land on sloping terrain be given to the peasants only on condition that they terrace the slopes and thus control erosion.⁵⁰

The need for the terracing of slopes became especially apparent in Java in the coffee lands that the peasants had to plant under the forced-culture system. Many of these lands were completely exhausted after a few years, and Holle showed that this rapid exhaustion occurred because the topsoil had been washed away by heavy rains. In 1873 he wrote detailed instructions for the terracing and cultivation of coffee lands.⁵¹ However, Holle's instructions and the stipulations of the Ordinance of 1874 were subjected to criticism and often ignored. In 1889, therefore, the Government of the Indies asked Forester Berkhout to investigate the practical results of the application of terracing to tegalans. Berkhout's report summarizes the arguments for and against terracing; these still make interesting reading.⁵² The arguments against terraces on tegalans were put forth as follows:

1. The people are not used to terracing dry land.
2. Terracing demands more labor.
3. It reduces productivity in the first year if the land is rather steep and the humus layer thin.

⁵⁰ Article 5 reads: "Dat bij hellend terrein zoo er gevaar bestaat voor afspoeling van de bouwkruijn, de aanleg geschiede terrasgewijze, en voorts onder zoodanige voorwaarden als plaatselijke omstandigheden wenschelijk maken." Ontginnings-Ordonnantie, *Staatsblad* 1874, No. 79.

⁵¹ *Nederlandsch-Indische Maatschappij: Handleiding*, 1873.

⁵² Berkhout: "Terrassenaanleg," 1892, pp. 139-141.

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ing crops. The process can be adapted to climate by manufacture either in shallow pits or low heaps."⁶⁴

Dry-Field Crops Cultivated by Peasants

The list of dry-field crops cultivated in Southeastern Asia is rather large, but there are regional variations. Cassava, for example, is commonly grown on tegalans in Java (2,300,000 acres), whereas it is unimportant in Sumatra, Borneo, the Philippines (40,000 acres), Malaya (24,000 acres), and Indochina (75,000 acres). The most important dry-field crops are up-

TABLE IV—CHEMICAL COMPOSITION OF CASSAVA AND
IMPORTANT CEREAL FLOURS

	CASSAVA (PER CENT)	MAIZE (PER CENT)	WHEAT (PER CENT)	RICE (PER CENT)
Moisture	10.75	13.41	13.65	13.12
Protein	0.87	7.56	12.35	9.85
Crude fat	1.19	2.79	1.75	0.88
Ash	1.24	1.78	1.81	1.51
Crude fiber	6.12	3.19	2.53	0.63
Carbohydrates	79.83	71.27	67.91	74.01

Source: The Cassava Industry in the Philippines, 1939, p. 7.

land rice, maize, cassava, sweet potatoes, peanuts, soy beans and other pulses, tobacco, and sugar cane, all of which are annuals. Of the first four, only upland rice is a native of Southeastern Asia, whereas the other three are natives of the New World and were introduced into Southeastern Asia by the Spaniards in the sixteenth century.

The inhabitants of Southeastern Asia have long relied upon root crops, fruits, leaves of various plants, and wild roots and tubers gathered in the forests, as well as upon rice. Scheltema refers to a number of early statements which indicate that "rice was not yet the principal food for a large portion of the native population [of Java] as late as the first part of the 19th century and that the rice diet has become much more important in the course of the past hundred years" as a result of the great extension of the cultivation of irrigated rice fields.⁶⁵ If it is correct that the rice consumption per capita increased during the past century, the opposite trend has been evident during the present century. For a while the increase in the area of irrigated land was great enough to allow for a larger rice production, but with the steadily increasing pressure of population the peasants now have to depend more and more upon unirrigated land. Thus the production of dry-field crops is gaining in importance.

Authorities in Southeastern Asia have been especially worried over the increase of cassava production and consumption. Because of the exhaustion of the soil fertility on many dry fields, the growing of upland rice and

⁶⁴ Worthington: Science in Africa, 1938, p. 387.

⁶⁵ Scheltema: The Food Consumption, 1936, p. 10.

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maize has become unprofitable, and many peasants have changed over to cassava, which makes lesser demands upon soil fertility. The per acre yields of cassava are high, and the plant is a source of carbohydrates, fat, and protein. From the standpoint of dietary needs, however, the ratio between carbohydrates on the one hand and protein and fat on the other is unfavorable. People who live on cassava merely fill their stomachs. The insufficiency of protein intake is detrimental to their health. Table IV⁶⁶ compares the chemical composition of cassava, maize, wheat, and rice.

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Maize, as the table indicates, compares quite favorably in protein content with wheat and rice and is especially rich in fat. It has gained an important position in the diet of the people of central and eastern Java, Madura, the island of Cebu, and the Cagayan Valley in the island of Luzon. Both maize and cassava are easy to store and therefore have a great advantage over sweet potatoes, which must be consumed soon after they ripen.

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In Thailand maize is an important crop on the Khorat plateau and in other regions where dry land is available. Among the root crops cassava has gained a greater importance than taro and yams. The last two are grown mainly by Chinese gardeners in the neighborhood of large towns. Cassava, too, is grown commercially by Chinese, especially near the railroad on the peninsula.

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Most of the so-called dry-field crops are grown in Indochina during the dry season on land that is flooded during the rainy season and at that time produces rice. Gourou has estimated that in Tongking 100,000 hectares of land are used exclusively for the production of dry-field crops and that 350,000 hectares of irrigated land are occupied by such crops during the dry season.⁶⁶

This practice of growing dry-field crops on irrigated land during the dry season is especially widespread in Java, where population pressure is so great that the peasants have to use every possible means to enlarge their food supply. If there is not enough water available to grow a second wet-rice crop, they will always try to get a second harvest of quick-growing dry-field crops during the dry season.

In contrast to the peoples of Java, the Filipinos do not, as a rule, go in for the raising of dry-field crops on wet riceland during the dry season, although this should be possible if the land were cultivated. There is enough water in the soil a short distance below the surface for the growing of crops practically everywhere during the dry season. Repeated tilling would keep the soil soft and fine so that water could move upward by capillary action to replace that which is lost through evaporation. Cultivation would enable plants such as maize, peanuts, and soy beans to grow on land that otherwise would be baked dry and hard. Although the ratio between cultivated land and population in the Philippines does not make a dry-season crop a necessity in most regions, there are a number of districts where the peasants traditionally raise a dry-season crop on irrigated

⁶⁶ Gourou: *Les paysans*, 1936, pp. 407-408.

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type which have been severely scarred by denudation. Magmatic rocks have flowed extensively from these volcanoes, spreading over a large area and serving to mask relief forms developed upon underlying earlier structures. As a result of these igneous formations throughout the region, contact metamorphism has taken place on a large scale, which has a major bearing on the frequency of metallic minerals and helps to account for the scarcity of coal formations.

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3. The detail of much of the Southeast Asia landscape is conditioned by contemporary river alluviation and coastal sedimentation (as in Eastern Sumatra and South Borneo) whose thickness and profusion relate to the rapidity of tropical erosion on the one hand and to the stability of the continental platform on the other. Relief upon the great alluviated landscapes is slight. In this zone where there is so much coastline in proportion to the land area, marine accumulations of spits, bars and off-shore beaches are both prominent and important in conditioning coastal topography and the location of settlements. Marine loads tend to be heavy in this zone of violent terrestrial erosion and under certain conditions sediment accumulates quickly owing to the speed with which mangrove establishes itself upon any bank or spit which is built up, thereafter further hastening deposition by hindering the free scouring of normal wave action. Marine sedimentation is greater upon the inner coasts of the Sunda Platform and less upon those coasts facing the Indian and Pacific Oceans where the shore profiles are steep and the waves have maximum fetch.

CHARACTER OF SEAS

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Three types of seas may be distinguished by the criterion of depth:

1. Shallow seas of the Sunda Platform
2. Shallow seas of the Sahul Shelf
3. The Austro-Asiatic "mediterranean" basins between the Sunda Platform and the Sahul Shelf, and subdivided by island festoons. In this group may be provisionally placed the Sulu Basin, though the South China Basin between the Philippines and the Asiatic mainland may only be included by considerably stretching the "mediterranean" conception.

Chapter Three

THE DRAINAGE PATTERNS OF SOUTHEAST ASIA

THE Irrawaddy, Salween, Menam Chao Praya and Mekong are remarkable for their length compared with most Southeast Asia rivers, which rarely exceed a few hundred miles long. Those four major rivers are associated with tectonic basins; relief elsewhere only permits short streams. All districts marginal to the Sunda Platform have experienced relatively recent tectonic changes and the rivers developed upon them are youthful as well as short. Upon the Platform itself much more advanced landscape maturity is evident but because this older surface has only limited areas exposed, rivers even there are short.

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CHARACTERISTICS OF TROPICAL RIVERS

In the régime of tropical rivers several factors have distinctive emphasis compared with conditions in temperate latitude rivers. Firstly the volume of water precipitated into and to be carried from any drainage basin is several times that of equivalent temperate latitude rivers as a result of the much higher rainfall. Moreover the precipitation is more intense. Even the dry interior of Burma experiences falls of rain averaging 6 inches per rainy day. The water content of those Tropical Air Masses over Southeast Asia is so high and the rising air currents so strong and sustained that several Javanese stations have recorded falls of over 16 inches per day. These violent torrential downpours are often very localised at any one time, yet on an average they affect large areas. Thus the volume of rainwater in any drainage basin is enormous and fluctuates widely within short periods of a few hours.

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A further consequence of these great rainstorms is their powerful erosive effects. Upon cultivated land the force and volume of these downpours cause surface downwash to be large, the soil rapidly washes away and whole hillsides may slip, so that the runoff has a high mud content. Because the rivers are mostly immature, this heavy load may be sustained by turbulence for considerable

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133 distances. In areas of alternating wet and dry seasons, drought cracks the ground, loosens the top surface and thereby increases the available load when the rains begin. The Dry Zones of Burma and Siam are for this reason areas of most violent surface removal. The very heavy load of Southeast Asia rivers gives them a great capacity for rapidly building up deltas, sedimenting the estuaries and at times causing heavy deposition of silt well inland. Furthermore the rainfall is not only violent and intense, it is also variable in seasonal incidence; thus many streams of Upper Burma, Central Siam and Eastern Java are for months practically dry and then come into spate within a few hours, not unlike the wadis of North Africa. Landform combined with the seasonal rains causes the Salween, for instance, to vary its level 50 feet within a few hours. Such variability of volume induces deposition well inland. Huge silt banks lie across many watercourses, vast alluvial fans develop at the debouchment to plains, and even at the junction of tributaries.

The Irrawaddy presents an example of how the drainage conditions differ at different points in the course of a tropical river. Near and above Bhamo changes of Irrawaddy level directly parallel changes of rainfall. As the stream passes through the Dry Zone of Burma it receives no significant additional water from the tributaries after it passes the confluence of the Chindwin and it is effectively losing water by evaporation. Stamp estimates 45 per cent of Irrawaddy water has been lost by evaporation when the stream finally reaches the head of the Delta. Evaporation rates in the Burmese Dry Zone are little, if at all, less than the precipitation. Farther downstream, in the Delta, heavy precipitation occurs again, so that the Irrawaddy floods arrive at the Delta roughly a month after peak rains in the reaches above Bhamo, to find it already suffering from floods due to local rains and small local streams. These floods of local origin effectively oblige the Irrawaddy water to remain within the main distributaries. Even more interesting is Stamp's evidence that the average annual silt load at the Delta head is 261 million tons, whereas at Mandalay it is only 32 million tons, showing that 229 million tons of silt is added in the Dry Zone. Since the Chindwin provides 109 million tons of silt, the balance of 120 million tons derives from the wadi-like, highly variable streams (chaungs) joining the Irrawaddy in its driest section.

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LOAD AND THE EROSION OF BASINS

Acting as a brake on the destructiveness of the rivers and on the changes of river levels, the dense forest cover of most of the landscape breaks the force of the downpours and provides roots and undergrowth to act as a spongelike retainer of water and as a partial filter of sediment. Under natural conditions, where the forest is undisturbed by man, this influence is so strong that even minor brooks are relatively clear, but where the natural cover is removed by burning to permit cultivation or mining, the brooks are thick and opaque with sediment, a condition rapidly extending as more and more surface is exposed for farming or for alluvial mining. Wherever there are active volcanoes, great quantities of loose ash are thrown out regularly; Southeast Asia volcanoes typically eject ash rather than lava. Unconsolidated ash without vegetation cover is rapidly washed into the streams and by these agents spread out over the estuaries. A new volcanic outburst is at once followed by heavier loads in the local rivers and increased estuarial deposition (Fig. 19) and greater danger of silting up irrigation and drainage canals which may have been built downstream for cultivating rice. That so much of Java's volcanic ash cones are terraced may only partly be ascribed to agricultural pressure; the terracing is equally necessary to control slip of the ash and to prevent sedimentation by waterborne ash from completely overwhelming the lowlands. Largely as a result of heavy ash loads, the Solo River, for example, carries some sixty times as much sediment as the Rhine, though it has only 40 per cent of its length. 134

The heavy load being carried away by the rivers lowers the surface of the drainage basin over most of its area, even though part of the lower basin is being built up a little by sediment. The rate of destruction of the drainage basin in the tropics is far higher than anywhere else. The Chindwin is removing the surface of its basin by .78 mm. per annum, the Irrawaddy above Prome by .52 mm. per annum, the Loesi in Java by .87 mm. In some small Javanese streams the destruction of the drainage basin has reached as much as 3 mm. per annum. As standards of comparison, the annual lowering of the Danube basin is at the rate of .006 mm., and of the Marne, .005 mm.

As a region, Southeast Asia is thus one of the least stable in the world, as far as orographic form and drainage patterns are 133 134

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133 concerned. Erosion here works faster and the associated deposition occurs at a greater rate than temperate latitude geographers allow for. This adds only a further variant to the general tectonic instability of all the zone fringing the Sunda Platform, but in the case of the Platform itself, its great age and relative stability plus the intensity of river erosion, provide an excellent case of a landscape exposed continuously to subaerial erosion for a period long enough to indicate an approach to the peneplainised state. The Malayan landscape, central to this continental Platform and exposed fully to continuous, powerful and prolonged river action, has special interest in this connection. In Malaya, large alluviated plains dominate the landscape and the hills rise sharply from these plains, yet the features of normal river types still persist. Rapids exist in a number of Malayan rivers, profiles are slightly broken at a number of levels, trellis drainage patterns have persisted on tilted strata (Fig. 32) and river capture goes on even at this advanced stage, as in the capture of the Bera headwaters by the Muar (Fig. 16). Lakes, however, are unusual on the main Sunda Platform; this negative point is at once a symptom of erosional senility and of the ability of tropical vegetation to build out into the lakes, hastening their sedimentation until the standing water disappears. Thus the Bera Lake of Malaya is really a large swamp periodically inundated; the Tonle Sap of Indochina is rapidly filling to become a similar swamp-lake varying with the seasons. Infilled swamp-lakes appear also in Borneo and the Shan Plateau.

133 THE GLACIAL PERIOD AND SOUTHEAST ASIA DRAINAGE

While tectonic and erosional changes have produced most variations in river forms of those parts of Southeast Asia fringing the Sunda Platform, upon the Platform itself, rivers have been more recently affected by a process of marine inundation. There is general agreement that the history of the Platform is one of stability or possibly of slight sinking; the uniform depth and terrigenous bottom material of the Sunda Platform seas, and also the fully-developed river valleys upon their floors, combine to support the view that a rise of sea level has taken place, associated with continental icemelt which took place in northern latitudes when the last Glacial Period closed. De Geer estimates that the last Scandinavian glaciation reached its peak some 25,000 years

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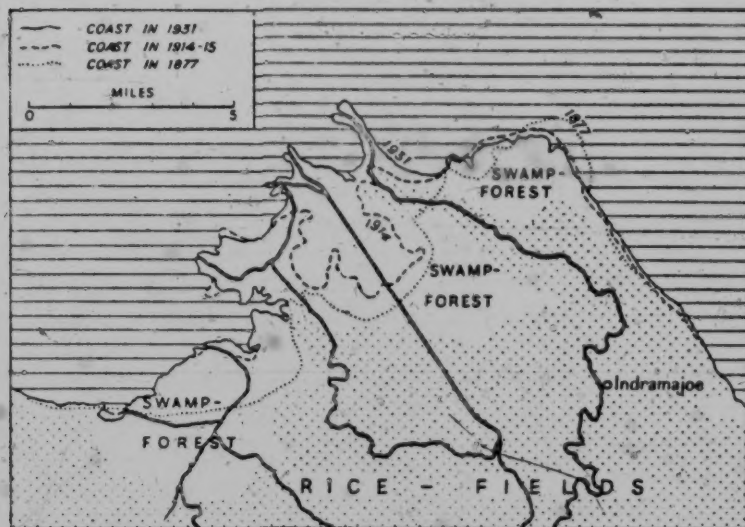


FIG. 19.—Coast Changes at the Mouth of R. Tjimanoe (Hoek van Indramajoe). This shows the rapid changes of the Java coast as a result of sedimentation

The history of inundation at first glance makes it surprising that ria forms have not appeared on the Sunda Platform; the explanation lies in the heavy sedimentation by the rivers and in the relatively soft laterised surface which would be presented to the rising sea and quickly moulded by it.

The glacial periods had little other effect in Southeast Asia; Weissman estimates the snow line in Northern Burma to have descended to about 9,000 ft. during the Glacial Periods. If this lowering of the snow line by about 3,500 ft. compared with today roughly indicates the condition for all Southeast Asia at the time of maximum glaciation, then in the equatorial zone where the present snowline is about 16,000 ft., no mountain tops of Borneo, Java, Sumatra and Malaya could have been seriously affected by snows, let alone by mountain glaciation. Interpretation of land forms in these units on the assumption of glaciation must therefore produce overwhelming evidence to counter such arguments.

SEDIMENTATION

Very heavy river loads, the decreasing carrying power of rivers, and the shallow seas of the Platform zone, combine to make rapid sedimentation of estuarial and coastal regions the characteristic

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of contemporary relief forms and drainage patterns. The rate of coastal advance seaward upon the Platform is in places phenomenally rapid; the Tjimanoeëk (Fig. 19) and Solo deltas in Java are extending at the rate of 100 metres annually, the Mekong at 60-80 metres annually. An outburst of volcanic ash increases the deposition by neighbouring rivers at the coast, though the behaviour of sea currents moulds the riberyne deposit in detail on reaching the sea. Mangroves and associated vegetation quickly establish themselves on sandbanks and cays so that at the mouth of the Perak, for example, an exposure of a bank for only a few days at a low water season is enough to permit vegetation to start there, hastening the rate of deposition by offering an obstruction to river outflow and thereby perpetuating the bank which in other settings might disappear by erosion during the next high water spell.

Where streams debouch into deep seas the rate of coastal extension is inevitably less, due to the greater thicknesses which must be laid for every outward extension, yet the Irrawaddy Delta is building outward at the rate of about 60 metres per annum; that the Irrawaddy can maintain this rate of building into a deep basin reflects its tremendous load and a physical condition which concentrates the deposition of this load at the outer edge of the Delta rather than over its surface. (See Chapter 9.)

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Because the rivers are steadily sedimenting the bed of their lower reaches, these are in fact generally being raised in level. Such a process cannot continue very far; when its bed is raised slightly above the surrounding land, the river easily changes course, and every large delta of Southeast Asia shows signs of frequent migration of distributaries. Old channels and distributaries in various phases of abandonment may be seen at nearly every river mouth. Most deltas suffer regular inundation at various times of the year facilitating farming for rice, which depends on either natural or artificially induced floods, in most cases derived from rivers. The process of spreading sediment over the whole delta zone goes on both by migration of distributaries and by seasonal inundations, so that the deltaic surface over a wide area is being slowly raised by sedimentation, making it progressively more difficult to irrigate the inner and higher sections of the deltas and in the long run causing the centre of gravity of irrigation steadily to move

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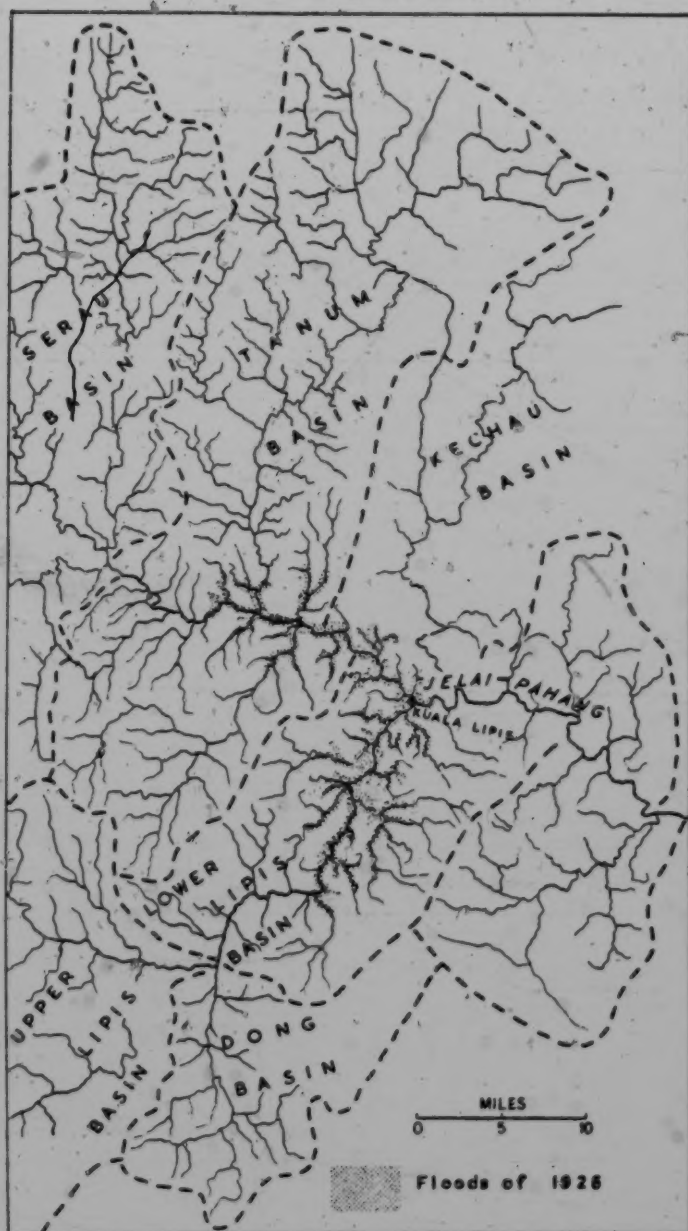


FIG. 20.—Flood Zones at the Junction of the Lipis-Pahang Rivers

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134 downstream, where also the newer unexhausted soils are to be found.

MARSHES AND SWAMPS

133 All land masses whose rivers empty on to the Sunda Platform are thus characteristically fringed with flat landscapes of marshes on a large scale. East Sumatra is an outstanding example of prolonged sedimentation by tropical rivers moving into shallow seas; this coastal marsh, at least 60,000 square miles in area, about a third of Sumatra, indicates what may result from equatorial sedimentation, here probably aided by a volcanic outburst in inner Sumatra during historic time (possibly during the century or so prior to A.D. 1000) and facilitated by the shallow Malacca Strait where the main tidal scour is to the east rather than to the Sumatra side. Huge flat islands have been formed off East Sumatra and they are regularly inundated by tides even now, so that they are in effect amphibious areas. The speed with which these coasts of sedimentation can advance and change should be taken into account when attempting to correlate historic place-names with sites and settlements of today. It may be that the decline of large principalities in Eastern Sumatra, reported in the first millennium by Oriental travellers, should be attributed to changes of coastline and to rapid deterioration of old site values.

FLOODS

A further feature of old drainage forms in Southeast Asia is the large size of inland swamps, as apparent in Malaya and Borneo. These arise from a combination of several factors:

- (a) the torrential downpours are often so intense that for a few hours the surface water is greater than streams can carry off, or subsoil can absorb;
- (b) the density of the vegetation cover impedes run-off;
- (c) differences of downpours in nearby rivers frequently cause a swift rise of level in one stream and not in another which it joins, so that at the confluence (Fig. 20) the stream in spate dams back the other and the flood may even flow into it, or build bars of silt across it. The Tonle Sap marshes suffer from Mekong floods in this way;
- (d) where a drainage system has cluse (as in Malayan streams) or similar constrictions (as in the Irrawaddy gorges) these features

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may induce flooding of the valley above the narrows. The Tasek Bera of Malaya in this way reflects constrictions in the Pahang Valley;

- (e) the presence of levees means that the zone between them and the foot-hills has difficulty in draining to the river after a flood or during a down-pour, so the levees are generally lined landwards by broad freshwater marshes, as by the rivers across the Korat Plateau in Siam (Fig. 90);
- (f) where local rain seasons coincide with the arrival of spates, originating elsewhere in the local rivers, the landscape cannot shed the direct rainfall rapidly and it induces marshes.

Most of the freshwater marshes are seasonally flooded, drying out quickly in spells of drought, draining when local streams are low, but then flooding to depths up to 10 ft. during wet seasons.

Some types of swamp are man-induced. When alluvial mining is being carried on, dredges and gravel pumps effectively stir up large quantities of river sediment which is carried downstream as the mining effluent (Fig. 21).

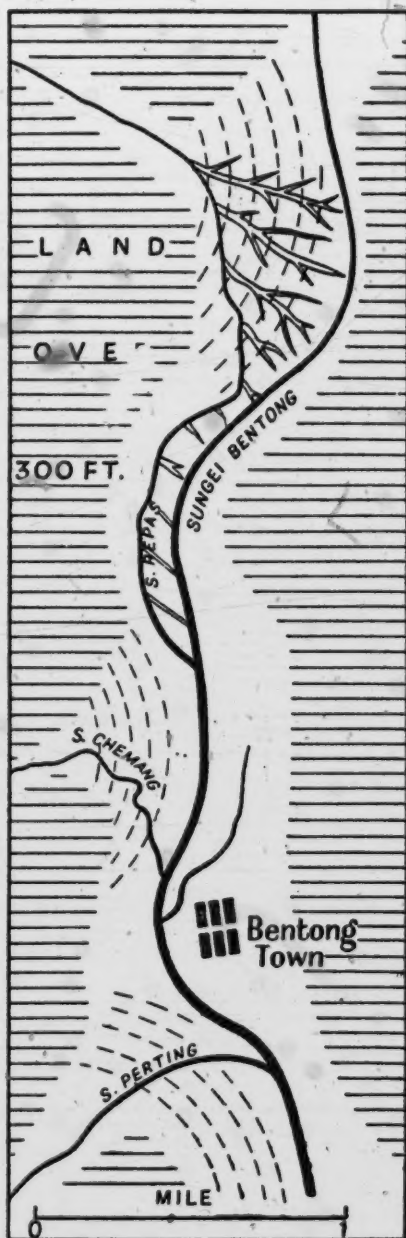


FIG. 21.—Alluvial Fans being thrust across Bentong Valley

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311 This artificially stirred sediment is agriculturally negative and
133 it penetrates the ditches and drains of rice growing areas,
241 gradually silting them up, often spectacularly raising the
• 134 local river bed (at Serendah in Malaya, the river bed was
raised 21 ft. by sedimentation over the decade 1923-33), as well
as sterilising fields on which the silt spreads so that cultivation
becomes more difficult as the river can no longer be kept out. The
yields decrease and the fields are abandoned, swamp vegetation
gradually obliterating signs of cultivation. Round the lower Malacca
River may be found signs of the old field bundings within the
tangle of swamp vegetation now growing there, a sign of the effects
of mining higher in the river whose effluent is obliterating cultivation
in lower areas. This type of swamp comes slowly and has all
the appearance of nature overcoming men's efforts to farm, but it is
fundamentally a result of man-induced erosions or abrasions elsewhere.
Thus interference, by mining and forest clearing, with land-
forms stabilised over long periods, not only goes on by removal
of silt and gravels carried from mining areas and topsoils removed
by torrential rains on clean-weeded agricultural areas as a mark
of transfer of surface materials from one area, but it also causes the
obliteration of cultivation and an extension of useless marsh in the
areas where this material is deposited.

133 Because these tropical marshes occur in zones of human significance,
361 that is, in the flatter areas with agricultural possibilities, and
along the coasts where settlement from overseas might take place,
they have played a major part in conditioning the distribution of
human beings in Southeast Asia. Both the coastal and inland
marshes are tree-covered, making it even more difficult to penetrate,
control, or cultivate them. Varying degrees of swampiness often
account for the ease of development of farming in one place rather
than another in Southeast Asia and a broad belt of marsh has
generally proved a greater human impediment than any other topographic
feature.

137 extensively because of their usefulness structurally and domesti-
 313 cally, but continuous stands become established only where the
 137 dry season is very marked and where shifting cultivation is known
 to have been practised extensively. Bamboos are giant perennial
 grasses of about a hundred species, with woody stems and woody
 roots. They grow in clumps and may be evergreen or deciduous.
 Some bamboos flower at long intervals (25-70 years) and their
 seeds are fire-resisting. Constant friction between the dry woody
 stems may cause forest fires and help to produce that selective
 process which leads to stands of bamboo.

• [134] Monsoon Dry Forest, an open wooded landscape containing
 very few species, may be found over large areas of Burma, Siam
 and Indochina in association with poor soils. Known as *indaing*
 in Burma and *padeng* in Siam, this forest develops where rainfalls
 are not much above 40 in. per annum, and it may merge on the
 equatorial side into Tropical Rain Forest and on the other into
 dry or thorny savannah vegetation. Within Monsoon Dry Forest
 trees are widely spaced, tending to be stunted forms of Diptero-
 carpaceae and distinctly deciduous.

Secondary Monsoon Forests.—Considerable areas of savannah
 found in Burma, Siam, Indochina and the Eastern Indies are
 secondary growths after a removal of the natural Monsoon Forest.
 Savannah is open country of tall, coarse grasses, occasionally having
 a few scattered bamboos or low trees and very much associated
 with long dry seasons whose effects are aggravated by poor or
 porous soils. Savannah merges into Monsoon Dry Forest and
 is often covered with low palms (*Borassus flabellifer*), and
 contains prickly pears, spiny cactus-like plants, and similar
 thorny scrub.

(3) MOUNTAIN VEGETATION

Vegetation steadily and often imperceptibly changes with
 altitude and the resulting types are much the same, level for level,
 throughout Southeast Asia. All but the very highest mountains
 are forested, though the trees on exposed summits are dwarfed;
 only in New Guinea and Yunnan are the heights great enough
 entirely to prevent tree growth and produce an alpine vegetation.
 Young volcanoes may be treeless for pedological, rather than for
 climatic reasons.

Above about 2,000 ft., at most points of Southeast Asia, large

Chapter Five

SOUTHEAST ASIA SOILS

FACTORS IN TROPICAL SOIL DEVELOPMENT

934 WHILE most soils of Southeast Asia have in common the fact that they have been evolved under conditions of plentiful moisture, they vary very considerably and the term "laterites," frequently used to describe them, is so broad that it misleads. In the tropics, as elsewhere, soils represent a synthesis of the inter-related factors of climate, parent rock, plants and animals, relief and drainage; a change in any one of these factors will cause a change of soil character. Time, too, plays a considerable part. If the factors operate for a period indefinitely long, the soil type conditioned by them will evolve until the soil represents a perfect balance or end product of them. When the forest cover is removed or a volcanic eruption throws out new rock material, certain of the factors are changed, the soil reverts to a more juvenile stage and its evolution begins again on different materials and may take a different form. Thus soil differences from place to place are often due to differences in stage of evolution, in the time factor.

Southeast Asia weathering is fairly uniform from place to place. It occurs without exposure to frosts or to wide alternations of heat and cold, but under conditions of warmth and heavy rainfall. Hence the weathering process is chemical rather than mechanical.

Those regions of Southeast Asia away from the Equator and having a markedly seasonal rainfall (as in the dry belts of Burma and Siam) may be described as subject for part of the year to equatorial soil processes where surface evaporation is nearly nil and for part to desertic soil processes in which surface evaporation is at a maximum.

The warm rainwater of tropical conditions, well carbonated and charged with the biochemicals of vegetal disintegration, breaks down the silicates, which form most rocks, into salts which are leached away, leaving the complex sesquioxides to accumulate in the soil. These may in turn undergo selective changes, all leading to the accumulation of clays. In the tropical heat of Southeast Asia

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lowlands these changes, known as the hydrolysis of the silicates, most involved phases of soil chemistry, take place very fast compared with those of European latitudes or of high mountains, and reach the "end-product" or mature stage quickly. On the Sunda Platform and the Sahul Shelf, prolonged geological stability has in any case brought the mature stage in local soils, but even the more juvenile types of soil on the younger volcanic structures are rapidly evolving towards maturity. Adding further to the complexity of Southeast Asia soils is the variety of rock types and the varied lengths of dry season towards the margins of the region. Thus the diversity is great, although differences in the soil end-products is lessened to some extent by rapid maturity under a single broad weathering type—the warm, damp tropical.

TROPICAL GROUNDWATER

With certain local exceptions, Southeast Asia experiences an annual excess of rainfall over evaporation. This means that there is a steady movement of rainwater downwards, percolating through the soil as a dilute solution of chemicals from the air and from plants, capable in turn of dissolving some solids in the soil. While some of the soil compounds are produced by the decay of vegetation, the plants depend on the groundwater to dissolve those which become plant nutrients and are absorbed through the root systems. Not all solubles enter plants; most of them are just carried away. The continued downward movement of the soil water effects a steady removal (leaching) of the solubles in Southeast Asia soils. While a thick vegetation cover continues to be in place upon the surface, replacement of some solubles by humus renewal goes on all the time, but once that vegetation is removed, the surface soil rapidly loses its existing soluble elements, receives no renewals, and becomes infertile, a factor making continuous agriculture a drain upon the soil which not only loses its qualities by greater leaching but in addition loses by that which is absorbed into the cultivated plant. Where, however, there are breaks in the cycle of leaching, as in areas having a dry season, the soil water is for a time subject to a condition where evaporation exceeds rainfall, the leaching ceases and there begins the accumulation of soluble plant nutrients or even the drawing up of solubles from depth by capillary processes. These zones, where soil impoverishment is seasonally checked, are those with dry seasons, i.e. from Central Java eastwards, in the

134 monsoon zones of the Kra Isthmus and northward into Burma, Siam, Indochina, a factor in the greater fertility, agriculture and population of those zones compared with the equatorial areas.

Solution by groundwater, however, is not peculiar to tropical latitudes—it goes on elsewhere. The distinctive point is that high tropical temperatures and heavy rainfalls give groundwater great power both to dissolve and to carry away special selections of the solubles. Easily soluble components of the soil disappear wherever rainfall and groundwater are ample, but the order in which sandy elements, clay elements and iron oxides (the main colouring element) are leached depends on the organic content and temperature of the groundwater. Water containing large quantities of organic material is a rapid solvent of clay and iron compounds; when groundwater is of this type, the silica occurring in the soil in the form of quartz remains scarcely touched for a long period, according to Glinka, causing the mature topsoil to consist largely of sandy elements bleached white by the removal of iron oxide colouring and the mature subsoil to show signs of re-precipitation of the iron oxide at lower levels. This is the process of *podsolisation*. On the other hand, where its organic content is low, groundwater breaks down any silica in the form of complex aluminium silicates faster than the other compounds and removes certain elements of it, so that there remains an upper soil consisting at maturity largely of stable clays and iron compounds, strongly coloured red, yellow or brown. This process is *laterisation*, the dominant soil process in Southeast Asia. The end-product of laterisation may be called laterite, a porous, crumbly-textured, bright red soil often hardening on exposure to the air and composed almost exclusively of clays and iron compounds, and much the same whatever the parent rock. Only in limited areas is this laterite fully developed; elsewhere the process has not reached its final or mature stages so that most Southeast Asia soils may more aptly be called laterised, that is, at an intermediate stage of laterisation. This stage may be assessed by measuring the proportion of silica to the alumina; the higher the silica content, the less laterisation has taken place (Polynov).

The whole process of laterisation involves very special aspects of complex chemical and physical changes which await the researcher for clarification.

The organic content of soils depends in turn on temperature

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which conditions the rate at which soil bacteria and fungi can break down dead leaves and other plant remains, first to the dark-coloured humus and then to chemical compounds. Thus there is a steady addition of decaying vegetable matter to the soil as trees and plants drop their leaves or die, and a continuous depletion of it as bacteria complete its breakdown. The balance between them is established by temperature and in the tropics where soil temperatures remain so steadily above 75° F. the breakdown by micro-organisms is considerably faster than the vegetation, profuse as it may appear, can replace. Thus the organic content of laterised soils is relatively small, and confined to a few inches of topsoil, beneath which practically no humic solids or liquids will be found. In vegetation-covered localities, shielded by the canopy of trees, where average soil temperatures may be well below 75° F., accretion of organic matter exceeds depletion, enabling humus to accumulate and form black-coloured soils.

Where the soil is waterlogged, a widespread condition in western Southeast Asia, bacterial action is hindered by the exclusion of oxygen so that, whatever the soil temperature, dead vegetation accumulates, often in the form of thick layers of peat. Altitude, by lowering the soil temperature for periods below the critical 75° F. (Glinka), is also responsible for variations in the humus content of soils. In Preanger (Java) for example, the top soil gradually changes from one with a slow humus content and red colour on the foothills, through brownish, with an increasing humus content at altitudes of 5,000 ft., to become dark brown or black at higher levels on mountains. The relative subsoils are red in the foothills, where laterisation predominates, and gradually change to dirty white at higher levels where podsolisation and bleaching are aided by the lower temperatures.

Examples of local podsolisation in the tropics have been observed upon parent rocks of exceptionally porous character, as in the coarse sands and sandstones of Banka, Borneo and Malaya over which distinct bleached earths occur. Why laterisation should be replaced by podsolisation under these conditions is not clear, but the sandy, white or bleached soils are unmistakable. Thin Secondary Forest is normally the vegetation cover of such districts, whether as cause or effect of the podsolisation has not been determined. Glinka quotes examples where excessive moisture and humus have bleached certain soils among laterites and notes that

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podsoils developed under these conditions in the tropics differ chemically from analogous types in temperate climates. He reports the possibility that white laterised soils may derive from rocks containing magnetite forms of iron, which will not break down into ordinary brownish oxides under weathering.

LATERISED SOILS

While the characteristic colour of laterised soils is red, some of them have bright yellow colours which, however, do not indicate any chemical differences, except that the various types of iron oxide are more intensely hydrated. The colour distinction is now held to be of minor importance. Sometimes a red mottling breaks the uniformity of the yellow colouring; this is thought (Pendleton) to be connected with aeration along dead roots of plants, which have now disintegrated. Occasionally the fine channel of a root can be seen at the core of such mottlings, cross-sections of which often have ringed or oyster-shell patterns.

Laterisation produces end-products not materially differing however different the parent rocks may be, so that tropical red soils develop to much the same appearance over granite and over limestone, although the rate of maturing varies. On the other hand, the chemical character of parent rock may show for a considerable time in the laterised soils. Thus, the igneous rocks of Sumatra and Java are in some regions basic and in others acid. The more acid type of igneous rock contains very little calcium and phosphorus, weathering slowly into poor soils, whereas the basic rocks initially contain more of these elements and release them readily, to weather in the tropics into soils whose composition makes them more fertile. The leaching continues rapidly, and at a more advanced stage of weathering the soils from basic rocks are no richer in these solubles than those from acid extrusions. This accounts for great differences in the agricultural potential of the flanks of different volcanoes in Java, where any thinly populated zone may safely be interpreted as a zone of soils lying over acid igneous parent rocks, or of over-mature soils upon basic parent rocks. Pedologists disagree as to whether mature laterites can be derived from every type of rock but the majority incline to accept this point of view. Pure quartz sandstone, however, resists laterisation and quartz veins persist unweathered long after the original rocks containing them have broken down.

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The term "laterite" (from L. later, brick), now limited to mature laterised soils, has had a history confused by varying definitions. It was used in India by Buchanan in 1807 to describe a tropical soil containing large quantities of iron, soft enough to be cut with a spade or mattock, yet rapidly hardening on exposure to sun and air into an excellent constructional material much used for tropical buildings. Afterwards the term became loosely used for any reddish

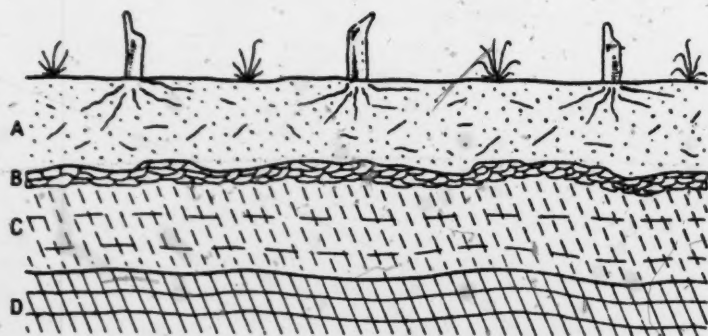


FIG. 25.—Section of Laterised Sandstone, Korat. Surface burnt for shifting cultivation. (a) Reddish-yellow sandy layer with tubular ironpan along old root-lines. (b) Lateritic ironpan and granular concretions, 6-12 inches thick. (c) Weathered sandstone, some bedding still showing, tubular passages (old roots), brownish-red. (d) Red sandstone of Korat, lightly consolidated, hardly deformed

tropical soils. Discrimination in the use of the word is modern and the standards are by no means uniform.

At best, only certain layers or horizons of laterite will harden on exposure. When this type of laterite is used structurally, being an end-product of weathering, it resists further weathering and buildings made of it stand up to the tropical climate better and longer than any other local material, evidenced by the old fort at Malacca and the temples of Angkor whose laterite slabs are firm and square after centuries of exposure.

Mature laterites may be up to 100 ft. thick, all weathered *in situ* and justifying the word "soil" to describe it. Several distinct horizons occur within this thickness. On top is a few inches of forest soil, dark with humus and partially decayed matter (Fig. 25). Under this is red earth, crumbly and sticky to the hand, permeable to water yet easily "baking" if ever exposed to the direct sun. Much of the water is held colloiddally so that percolation wells can rarely be used in laterised ground. Four or five feet below the surface a

134 distinct cellular structure develops, consisting of a coarse network of iron compounds round softer cores of clay. This is the horizon which may be of that hardening type suitable for a structural material. Sometimes the iron compounds at this level change *in situ* into hard concretions like a pan roughly paralleling the surface and looking like a lustrous slag. These crusts or concretions ring like hollow iron and might be mistaken for volcanic material. Containing up to 30 per cent of iron, they have at times been smelted, but extensive use for this purpose awaits development of a suitable

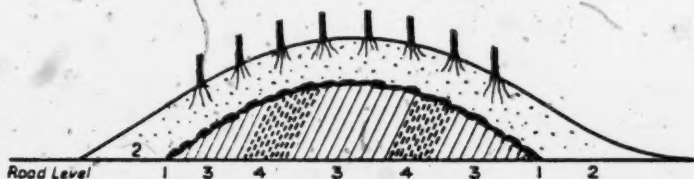


FIG. 26.—Section in West Singapore: Hill with Partially Removed Rubber.
1. Lateritic ironpan running across bedding planes. 2. Red subsoil, 3 feet thick. 3. Partially removed shale. 4. Conglomerate

process. Oxide of manganese occurs in these concretions as well. The pan may be continuous beneath a large area and prevent percolation, and in deforested areas the softer topsoil may be washed away, or slide down the surface of the iron pan which then shows as a compact platform inhibiting secondary vegetation.

The concretion of iron compounds is thought to be connected both with seasonal variations of the subsoil water level and with electrolytic changes in descending water heavily charged with solvents. Fracture planes, by creating internal drainage lines, encourage panning to follow lines unrelated to the surface contours. Skew-panning may also develop strongly along lines of quartz which persists undecomposed through thick laterites. While the iron concretion layer has special interest because of its resemblance to pan layers in other latitudes, it is by no means ubiquitous and some writers relate the pan to igneous parent rock. The stratifications of laterised soils are more related to the relief of the surface than to stratifications of the parent material (Fig. 26).

Beneath the concretion layer is another horizon of almost continuous saturation where the coloration tends to be less red and more yellow or whitish right down to the horizon of decomposing rock. These deeper horizons represent less advanced stages of

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weathering, repeating at depth some of the variations noted at the surface in less maturely laterised soils elsewhere.

Cuttings through laterised soil, as for roads and railways, frequently develop a dark crust after exposure, giving the sides of the cuttings an appearance of hardness belying the soft soil beneath it. Occasionally these exposures are honeycombed where softer parts have been washed away by rains, leaving the cellular structure of iron compounds fully evident. Because laterised soils are so wet and thick, the destructive processes of slumping and slipping assert themselves strongly. Soil creep on slopes operates relatively fast, particularly if an iron pan exists not far below the surface. Whole sections of a hillside may thus slump down into a valley leaving a scar which wild vegetation needs a long time to conceal. Road cuttings frequently slump at the sides as though huge spoons had been used upon them. Almost any ditch will show soil creep in the form of root-matted topsoil hanging well out over the side of the ditch.

POLYNOV AND LATERISATION

Polynov in his "Cycle of Weathering" has discussed a new interpretation of lateritic soils. Previous pedologists have considered laterisation to be a process peculiar to the high temperature and heavy rainfalls of the tropics. Polynov produces an argument to show that laterised soils may result as the end-product of weathering in any latitude, given a sufficiently long time for the process to operate. In his view the frequency with which laterites occur in the tropics now is due less to the special character of weathering there, and more to its rapidity, which brings soil maturity very much faster than in cooler latitudes. The age and stability of the Sunda Platform and the Sahul Shelf fit into both schemes since soils upon them may be considered to be brought to maturity by uninterrupted weathering during prolonged geologic time, and by the intense and continuous nature of tropical weathering. Whatever the value of Polynov's theory from the soil chemist's point of view, it helps to account for red soils of lateritic aspect outside tropical areas without needing to postulate major climatic changes.

SOILS IN THE DRIER ZONES OF SOUTHEAST ASIA

Northward from the Equator, Southeast Asia is subject to a longer and longer dry season during which soil leaching diminishes. On exposed soils, the high surface evaporation of dry periods even

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induces an upflow of groundwater which evaporates and thereby precipitates solubles in the topsoil. These have sometimes been called the Savannah Soils, found extensively in Siam and Indochina. The type occurs not only where the climate permits but also where destruction of marginal Tropical Rain Forest has gone on at a rate faster than natural replacement. Because tropical forest soil works with a very small quantity of plant nutrients circulating rapidly in a cycle from soil to leaves and back again to soil, the balance is delicate. Where the forest is almost virgin, natural fires do little damage, but persistent burning by men may break the cycle of nutrients and release altogether the small initial capital of solubles. The iron concretions under such conditions become firmly cemented into subsurface platforms inimical to anything except coarse tropical grass and the topsoil is exposed to rapid removal by torrential storms. The more accessible laterites which received early examination were often under vegetation of the savannah type and they were thought at one time to be signs of a change of local climate, from Equatorial to Savannah, whereas in fact they reflect over-destruction of the original tropical forest, followed by such a change of soil type that the forest cannot re-establish itself. Because laterite is very porous, rain falling upon it may be heavy yet quickly passes beyond the reach of plants, carrying all plant nutrients away, thereby preventing regrowth of the original vegetation cover.

Natural savannahs in Southeast Asia are noteworthy for their extensive iron concretion layers which provide support for the view that vertical fluctuation of subsoil water is a factor in the formation of lateritic iron-pan.

SOILS AND AGRICULTURE

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The different types of tropical forest induce minor differences in the soils beneath them, which assume major significance when the forest is cleared for cultivation. The limited supply of plant nutrients explains that paradox between the apparent fertility of an elaborate and profuse forest vegetation and the poverty of the soil when the forest is removed, the cycle of nutrients broken and most solubles washed away. Eventually clearances in the forest mean an increase in the outflow of nutrients in solution or suspension which are finally distributed into the swamps, the estuaries and the sea. To some extent the practice of burning, which reduces the forest to

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ash, lying for a while upon the surface, returns to the soil part of the chemicals of plant structure, yet unless steps are taken to retain this "capital" by terracing or cover crops, the ash quickly dissolves and disappears into the streams. Good crops may be obtained by utilising this soil capital immediately, but it can last only for a season or two, after which the natural infertility of laterised soils becomes apparent. It is not so serious with isolated native clearings, done under the shifting cultivation system, because each clearing is so small, and surrounded by forest, that lost soil nutrients are not carried far before they are recaptured into the forest ecology by the tangle of adjoining vegetation. When shifting cultivation is done too frequently over the one patch, that is, more frequently than, say, once in twenty years or so, then progressive impoverishment of the soil takes place. Maintenance of fertility in clearings is easier in less maturely laterised areas and where there is at least a short, dry season to interrupt the depletion processes.

The basic volcanic rocks of Java as well as the recent ash and mud flows contain chemicals which weather to plant nutrients and, being in addition very young in the laterising cycle, they produce fertile soils. On the older lavas and on the acid outpourings, a maturer stage of laterisation has been reached to produce soils no better for agriculture than other parts of the Sunda Platform. A new volcanic outburst, while creating temporary havoc, may ultimately produce local agricultural prosperity because it brings a new supply of plant nutrients. The elaborate terracing of new volcanic ash landscapes is only partly due to population pressure: it equally reflects the need to restrain the run-off and to hold back the solubles as long as possible.

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Apart from the loss of soil fertility due to rapid solution, all bare or clean-weeded soils in the tropics suffer from mechanical erosion by the violent torrential rainstorms. Rainfall of tropical intensity rapidly gullies all bare landscapes and is particularly evident on the less cohesive ashes of volcanic cones, so that another reason for terracing is to offset gullying. Tangled vegetation prevents mechanical soil erosion having any great significances in forested areas, but in Java, where recent ash and intensive cultivation combine to facilitate this type of erosion, rivers contain from 300 to 2,000 gms. of silt per cubic metre; the Irrawaddy has about 750 gms. suspended in each cubic metre. (The Seine and Rhine only contain about 50 gms. of silt per cubic metre.) From tropical forest in a

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natural state the soil loss is mainly by solution, and streams running from the jungles are either clear or black with humus content. From clearings, whether natural or artificial, subsoil solution is supplemented by violent mechanical erosion, and streams from these zones are thick and muddy, often tinted red.

Since both the subsoil processes and the surface erosion have water as their principal vector, the solubles and the silt are carried to the deltas and to the freshwater swamps which are the depositories of plant nutrients from all the forested soils. The coastal and freshwater swamps are not subject to rapid decomposition and they progressively accumulate plant foods, hence they function as the chief agricultural areas, continuing to produce without serious soil exhaustion through years of productiveness, as in the Irrawaddy and Menam Chao Praya valleys. These sticky wet soils are black or dark brown, often containing lenses of peat, and completely unlike the laterised soils around them. They are all transported soils, both fluvial and marine sedimentation playing some part in building and shaping them.

162 cent of the population. Malaya, of course, is exceptional, because of the
 565 especially heavy concentration on the production of rubber and tin. Ac-
 241 cording to the 1947 census of Malaya, about 34 per cent of the working
 463 population were classed as cultivators and fishermen working on their own
 32 account or as unpaid members of families. In all, I think one could reckon
 462 that rather more than 100 million people in South East Asia can be re-
 garded as peasantry.

[412] Throughout all this region, peasant technology is simple; skills, though
 134 traditionally well adapted to the job in hand, are of limited range. Soils,
 241 despite the richness of some of the swamps and river flood-plains, are
 generally of poor quality. The system of felling and burning the jungle,
 taking off crops for a few years, and then moving away to cultivate fresh
 clearings while the old ones revert to jungle, is still common in the moun-
 tain areas of Burma, Malaya, and Siam, in part of West Java, in much of
 Borneo, and in the outer islands of Indonesia. It is known as shifting culti-
 vation or jungle-fallowing. Although regarded as extremely primitive, it is
 an economic use of land in areas of low population density, where plentiful
 land allows of long rotation of clearings and consequent restoration of
 soil fertility. But where population is dense, the system cannot provide the
 necessary volume of production without endangering the future soil capital,
 and that is one of the major problems of the area. In the more sedentary
 forms of agriculture, fertility is conserved with a great deal of care, by
 manuring, by water control, and so on. Sometimes there is very elaborate
 and spectacular terracing, as in parts of the Philippines or in Bali, where
 the native cultivator through his own efforts through generations has
 known how to make the best of the land with his available techniques. Yet
 many of these techniques are only of limited efficiency, and custom may be
 a barrier to improvement. For large masses of the Muslim peasantry of
 South East Asia, for instance, the pig, an excellent economic converter of
 resources, is taboo for religious reasons.

433 Productivity of the South East Asian peasant is apt to be low, whether
 241 considered in terms of the margins required above subsistence to give him
 565 and his family the range of goods and services they want, or by comparison
 with Western results. It is hard to make this last comparison significant
 because of the differing bases, but the following figures will give, perhaps
 rather superficially, some idea of the comparison. In terms of cwt. of crop-
 ping per acre, for instance, the rice crop of part of South East Asia can be
 compared roughly with the wheat crop of Western Europe. The figures
 are taken from different years, but they can be regarded as significant
 averages. Java at 12 cwt. of rice to the acre corresponds with France at
 12 cwt. of wheat to the acre; Siam at 14 cwt. to the acre with the United
 Kingdom at 18 cwt. and Germany at a little less; Japan at 27 cwt. of rice
 per acre corresponds to Denmark with 27 cwt. of wheat per acre. Yet rice
 is supposed to be a crop of much higher yield. What is more significant is
 that productivity per acre in both Malaya and Indo-China is only 10 cwt.
 on the average, or only between one-third and
 one-half of the average in Japan.